PRESIDENT'S ADDRESS.

WHAT HAS THE FUTURE FOR GEOLOGISTS?

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At the last meeting of the Ohio Academy of Science we had an able review of the accomplishments in the field of Geology during the last quarter century. Today I want to ask you to look with me ahead perhaps even farther.

In my desire to take this forward look I am prompted by a question put to me more than a year ago, by a man with wide experience and observation. His question was the one in my subject: "What has the future for the Geologist?" And he added (by way of comment) that to him it seemed that the days of the Geologist were limited; that there was little more to do in this science except to conserve what knowledge we have and hand it down from generation to generation. He further granted that General Geology had a cultural value and hence should continue to be taught in our Colleges and Universities. His question may have been suggested by the fact that several State Geologic Surveys have already issued what purport to be "Final Reports."

I had not really taken stock in the manner best suited to provide me an answer to his question, but I felt quite sure he had underestimated our ability to find a job. I have therefore been hunting for the answer to his question for more than a year. In this connection I want to say further that if *this* man had not had time to look up the future for Geologists more thoroughly than his comments suggested, there may be others who have not taken time to see the new horizons.

It may not be any more amiss for a Geologist to consider his market as well as his equipment than it is for a merchant to study the needs of his community, as well as his stock in trade. Furthermore I must needs make my appearance here today; and the matter freshest in mind and most vital to my kind, may be more acceptably presented than matter less fresh and less vital, though more thoroughly known.

Well might the Geologist be proud if he had mastered his field and there yet remained nothing to do but to conserve his stock and perpetuate his race. We are ready to grant that geology is a cultural subject of no mean proportions, and that able teachers should be continually turned out to apply this culture to the rest of mankind. We believe men and women can live better for the vision a survey of our science can give, and we wish that many more than at present might gain that vision. But we are not ready to grant the rest. We believe that Latin and Greek are dead languages and yet that they have a cultural value and should be taught to large numbers of young people by competent teachers, and that a few of these young people should pursue the languages far enough to become in turn competent teachers.

We believe that geology is not in its coffin, nor on its dying bed. To establish this belief one can profitably note what yet remains to be done in several geologic lines, and the present rate of progress along these lines.

1. In the field of topographic mapping, the first serious work undertaken in any new region by our Federal survey, there is yet something to be done. The United States and Alaska are large enough that when mapped on the scale now most generally used, one mile equals one inch, 16,000 sheets will be necessary to contain them. We have been making these maps at the rate of some 200 per annum recently. At this rate eighty years will yet be needed to cover our land. And this is only preliminary to geologic work. This scale is much smaller than is used for the more refined work done in England, Switzerland and Germany. We have a few sheets for important mining regions or other special places on a larger scale. See California Alluvial Valley; sheets of Grand Canyon and Yosemite, Aspen and Mother Lode regions. Perhaps 35% of Europe is topographically mapped on some scale adequate for other geologic work. Portions of Egypt, all of Palestine, portions of India, China, Brazil and South Africa, patches in Australia, most of Japan and New Zealand, and small areas in Southern Canada are also mapped. Nearly all, however, of the earth outside of the United States and Europe is still unmapped on such scales, and progress thereon will be generally slow. When the United States and the countries of Europe have completed their work at home they will find many years of work yet to do in other continents. When most of the land is mapped on a scale of one mile to the inch many areas can very profitably be mapped on

a larger scale for more refined areal geology than can be done on the smaller scales.

2. In the field of areal geology—mapping by means of colors or designs the distribution of the rocks of each age or kind—the present time finds relatively little territory covered. In the United States about 200 folios have been published. Each covers from one to sixteen of the one inch to the mile sheets, or in all, about 850 quadrangles, or nearly 200,000 square miles. At the present rate of progress our country will last the Federal survey nearly 500 years. It may be said, however, that a good deal of work has been done by State surveys of about the same quality, some even better, and that this time may be cut down one-half. The countries of Europe are not as a whole far in advance of the United States, and most of the rest of the world has not been disturbed by any such refined work.

Mapping on the scale of one mile to the inch does not call for careful enough field work to even open many of the problems of geology. Some of our State surveys, some private companies, and occasional parties in the Federal survey have undertaken local studies of a much more detailed nature than the general run of work on the above scale. For example, see Butte, Montana, and Bisbee, Arizona, regions.

Geologists have made many generalizations and have built up many working hypotheses for all kinds of purposes. Of course, the work in the field upon which they are built has not yet gone far enough to thoroughly test the validity or falsity of either the generalizations or the hypotheses. Not until the evidence is all in can we say the laws are known. Better working hypotheses and more reliable statements of principles are appearing every year in the various fields of geology, while the older theories and statements having served their day as stepping stones are cast aside. Even in the mapping of areal geology and the interpretations thereof, the field is almost infinite, if the whole world be taken into account, and the scale be large enough to show what details can really be seen.

3. In the field of stratigraphy and stratigraphic interpretation the Geologist uses the areal work just discussed and attempts to unravel the succession of events—the chronology of geology. It is by this means in part that he has been able to assign units of time to his geologic history of the earth. Breaks

in the succession of rock layers indicate breaks in the process of sedimentation. Such a break is called an unconformity. The size of the area over which the unconformity extends and the amount of the break are used in determining the rank of the unconformity, i. e., whether it shall be used simply to mark the limits of two formations, or to mark the boundary between two systems or groups of rocks, or two periods or eras of time. Just as birthdays count off years so local and slight breaks or changes in the sedimentation mark off short time units; and just as centennial and millennial celebrations mark off hundreds and thousands of years, so widespread unconformities and great breaks in the geologic record mark off the larger periods and even larger eras of time.

In recent years unconformities of considerable significance have been found where they have been passed over unnoticed before. Perhaps others are yet to be found; and probably some now known only locally will be found to be very extensive. It is only by the careful study of hundreds or thousands of exposures over broad areas and the most judicious correlation from place to place that the facts of the extent and the amount of a given break can be known. Here then, is ample reason for the most detailed stratigraphic work over all known lands.

If enough were known of the unconformities and the character of each layer of rock wherever it occurs, it might be possible to plot on a map the distribution of lands and seas at any given time. Such mapping and the interpretation that goes with it is called paleogeography. It has been but a few years that men have had sufficient data to attempt such mapping. The first maps were supposed to give the extent of seas, bays, gulfs, and land areas for a whole period. They were in the same order of accuracy as a historical map of Europe which should attempt to show on a single map the distribution of the nations through the whole Christian era. In Europe in 1915-16 it is necessary to date the map to the month and the day to make it right. Paleogeography cannot be considered far advanced until it can produce one map for each of a hundred or more dates throughout the earth's sedimentary history, not only for one continent, but for six, with some intercontinental connections. In order to make such maps it will be necessary to have an enormous body of data for the area and for each particular horizon mapped. We cannot hope for perfect maps of sea and land, rivers and mountains, shorelines, islands, straits and bays for every horizon over large areas; but if we knew all the facts now recorded in the rocks of North America we might be able to make a map for each of many horizons, which would be of profound significance and interest to the paleontologist, the biologist, the economic geologist and the geographer.

Many paleogeographic maps have recently been made. One set of about fifty by Charles Schuchert, of Yale, is a marvel of what the paleogeographer can do. The series of final, correct maps of a continent can not possibly be made until all the continent has been mapped areally, and all correlations of strata and unconformities have been established.

All stratigraphic geologists are interested in making as complete a columnar, stratigraphic section as possible. Manifestly such sections in separate localities cannot be alike. unless the localities had the same conditions at the same interval throughout all of geologic time. The correlation of all sections one with another is a step in the making of the paleogeographic maps, and in the interpretation of the stratigraphy of a continent. Such correlation is done on the basis of rock character and fossils. Let me quote a few lines from Schuchert, in Pirsson and Schuchert's Text Book in Geology, page 450, which may contribute to the problems, both of unconformities and the making of the column. "These breaks are known to be many, but they are far greater in number, and their time durations, although admittedly very variable, are far longer than is usually believed to be the case. The geologic column will probably never be completed on the basis of the recoverable physical and organic evidence, but it will grow into greater perfection for a long time, through the discovery of formation after formation along the lines (levels) of these breaks."

4. The Paleontologic record in the rocks is largely yet to be deciphered. At present every paleontologist recognizes great breaks in the biologic succession. So numerous and great are these gaps that the theory of evolution of later from earlier forms cannot yet be considered a principle or law. Not until a column is completed, and that too of fossiliferous strata, can we know just what has been the succession of forms. The paleontologist must go on collecting as the study of areal

geology proceeds, and the paleogeographic maps grow, and multiply, and the columnar section becomes more complete, until such a time as he can have a complete series of forms from the beginning to the present. Then he may be able to answer the great question whether each flora and fauna has developed from a previous *ensemble* of life by gradual transitional changes, or has arisen by a sudden large change, or a creative fiat at some critical moment. Since this work of a biologic nature cannot precede, but must follow the stratigraphic and paleogeographic work it means many more years and probably centuries before the geologist need lay down his hammer and spade.

If there are *enchainments*, to use Gaudry's term, between species of one period and those of the next, our field studies ought to find them. Very few have yet been found, but in most cases there is rather a biologic hiatus. I have faith to believe that within the next thousand years or so a considerable number of real *enchainments* will be established. We may also find many actual centers of dispersion where the evolution of a fauna has gone rapidly forward in a more or less restricted area and from which the new forms have spread in startling suddenness and profusion. Indeed it is possible as we push our research farther and farther back and finally have mapped and studied minutely all stratified rocks from all parts of the earth that we shall find the beginnings of many of our large types of life. We may even find substantial paleontologic evidence for the evolution of man from the lower, more primitive and generalized mammals.

A few figures will present the biologic possibilities in a very different way. Pratt in 1911, estimated the described forms of animals to be a little over a half million. A recent estimate of the number of fossil animal species described gives 100,000. The 500,000 living forms were taken from one geologic period at one time. The 100,000 fossil forms were taken from the whole geologic section, which undoubtedly includes hundreds of geologic "times," any one of which was as long as the present, had as distinct a fauna as the present, and perhaps as many species with hard or preservable parts as we have now. Of course, our recent 500,000 described forms does not include nearly all of the living forms, possibly not 20%, and this ratio may be similar to the ratio of animals with hard parts to all animals. Probably too, life has become more diverse than it was in the early geologic times, but after making all necessary and reasonable allowances, it seems probable that we do not yet know one per cent of the forms that have lived and possessed hard parts, and certainly not more than one-tenth of one per cent of all forms that have lived. Butterflies are preservable in the geologic record. Twenty-two species have been described half of which came from one place and one horizon, while there have been described of living forms about 13,000 species. With this present incompleteness of our knowledge, is it any wonder that we do not succeed in establishing biologic concatenations as frequently as we wish? And how long will it take to discover the rest of the 10,000,000 preserved species? So far we can agree with a statement of Huxley that "the whole geologic record (at least so far as we know it) is only the skimmings of the pot of life."

5. In the field of dynamic geology—vulcanism, seismology, diastrophism and gradation—the last process is really the only one which we know. We cannot expect to understand vulcanism, a perpetual and almost universal process throughout geologic time, though not as much so as gradation, until at least all present volcanoes have been carefully studied for time sufficient to know their habits as well as we know those of Vesuvius. We have been nearly 2,000 years learning Vesuvius, and there are 500 living volcanoes, with 3,000 or more that are dormant or recently extinct.* Not only should we know their distribution and habits, but their connections and interrelations, the depths from which they draw their lavas, and many other items to be obtained only by careful and long continued observation of each volcano. Generalizations on limited observations of a half dozen volcanoes cannot be considered final. Centuries of study of hundreds of vents cannot be counted extravagant when one is after such fundamental and deep-hidden truth.

Earthquakes have but begun to tell their story. Many records of all the larger quakes should be made. Then comparisons and computations may disclose facts not only about earthquakes, but about the nature of the earth's interior.

6. On this latter problem—the earth's interior—so little is known that we feel that we *know* nothing, except that its

*Pirsson and Schuchert, Text Book in Geology, Page 204.

substance is heavy. With long continued and wide-spread study of vulcanism, seismology, and the igneous and metamorphic rocks themselves, we ought some day to answer some of the questions asked by the laity, even if we still fail to answer our own interrogations.

On the question of the nature of the interior of the earth, Chemist, Physicist, Mathematician and Geologist must each work for some time. I confess that we do not yet seem to know how to attack the problem. I think it is certain, however, that much study of vulcanism, diastrophism and seismology for a long time over the whole earth, and of the first two through the remote geologic past, will make great contributions to our interpretative theories of the earth's interior. Physicists and Chemists must help before the problem will yield, and it seems evident, even with these several scientific cohorts in siege, that the secrets will be only slowly and reluctantly surrendered.

7. With these problems comes that of the origin and nature of both igneous and metamorphic rocks. Three recent enlightening books on igneous rocks leave us not far, relatively, from where we were before their authors wrote, and this not because they wrote so little, but because they do not yet get together and because their data are still quite insufficient. Rock and mineral analyses are now on record by the tens of thousands, but there are not enough. Nearly all have come from rocks collected between latitudes 25° and 55° North and on but two continents. The rest of the earth has its contribution to make.

Daly* estimates that the sedimentary rocks, if spread uniformly over the earth, would make a layer one-half mile thick. The metamorphics would probably not be more than two or three times as much. It is assumed then that the rest of the earth to the center is of igneous rocks. "The final philosophy of earth history will therefore be founded on igneous rock geology."† But with essentially all the earth consisting of igneous rocks it is evident that our meager scratching on but 10–15 per cent of the surface of the earth cannot give us more than an introduction to the problem of Igneous Rocks. Daly adds, page 42: "The data for a quantitative study of the visible igneous matter in the earth fall far short of being complete enough for the ultimate needs of petrogeny." And

*Daly, R. A., Igneous Rocks and their Origin, Page 1.
†Daly loc. cit.

Harker† says: "A systematic treatment of igneous rocks on the lines of petrogenesis is not to be expected in the immediate future."

One attempt has been made to correlate remote igneous rock sections, viz., between Scandinavia and the Adirondacks. When we know enough of petrogenesis we may be able to correlate volcanic rocks pretty generally even as we do sedimentaries.

Concerning metamorphic rocks we cannot yet tell in many instances whether the specimen was made from sedimentary or from igneous rocks, and until methods for making such identification are found many stratigraphic and regional petrographic problems remain unsolved. And until we understand much more than at present of both igneous and metamorphic rocks we shall be in the dark on the nature of the earth's interior. Right here some day, however, as suggested above, we may look for important light on cosmic geology.

8. In the field of Economic Geology have been gleaned many facts. This is particularly true in connection with some of the richer ore deposits and especially in the United States, Europe and some English and German possessions. It is very difficult to say what more there is to learn in this field until more progress has been made in areal and petrographic geology. It certainly is true, however, that in three-fourths of the land surface of the earth but little is known regarding its deposits of mineral wealth. Discoveries of new and valuable deposits have been made with at least the usual frequency right down to date, and there is no reason to believe that we are near the end of such discoveries. They may reasonably be expected to continue for hundreds of years as our exploration of the stratigraphy continues over the rest of the earth, first in temperate zones, North and South, then in equatorial regions the world around, then in the high latitude lands, and finally as exploration of the igneous rocks is also prosecuted in all latitudes and longitudes.

Moreover, new uses may be found by geologist, chemist, or manufacturer for substances now neglected or little used, and the geologist must then explore for the deposits of the newly desired substances. There is, I believe, a great field for invention in the combinations of metals and semi-metals, and in the

†Harker, A., Natural History of Igneous Rocks, Page 376.

uses to which many substances can be put; inventions which will start the geologist and miner out anew.

May we not yet find unknown sources of heat, fuel, or electricity in the substances of the earth? May we not again find, as we have in the past, wholly new combinations or occurrences of elements?

Under this heading thus far I have really spoken of nothing but the purely economic possibilities. From the geologic side generalizations are now made on the basis of our studies of the deposits mentioned above; but such generalizations and any classification of ore deposits based upon them must necessarily be subject to continual revision as new discoveries are made. In some types of deposits I suppose our interpretations are fairly reliable. But some of our largest salt deposits, many gypsum and more anhydrite deposits are still in dispute. Hundreds of deposits of sulphides, tellurides, selenides, etc., are still under discussion. Whether of magmatic origin or segregated from the sedimentary rocks in joints of which they lie, or whether deposited by ascending juvenile magmatic waters, or by waters once at the surface, and now, after a journey down to high temperature depths, ascending with sufficient solvent power to segregate the ores, is still an unsettled and, just now, indeterminable question.

In many instances the ore deposit is intimately related to igneous rocks and cannot be understood until the story of igneous rock genesis is written. Lindgren* says, too, that "rock alteration is a subject of prime importance for the mining geologist." While this subject has long been studied, but little has been done in rock alterations beyond those changes that make rock waste. Alterations that make rocks over, andesites and limestones into highly siliceous rocks, black diabases into white rocks made of calcite, quartz and micas, are but little understood, and many analyses and comparisons must yet be made. And conversely, because of this relation of igneous rocks to ore deposits, the interpretations of the latter will certainly help to elucidate the genesis of the plutonic rocks. We have no right to ask to be excused from geologic research until the metaliferous deposits have all been studied. How long a job this is we cannot know, because we do not know how

*Lindgren, W., Mineral Deposits, Page 2.

many deposits are yet to be found. It is reasonably safe, however, to estimate that the known problems and occurrences will keep the geologist busy for some generations.

All these problems relating to the genesis of mineral, rock and ore deposits, those relating to the nature, and change of nature, of the earth's interior, those of vulcanism, seismology, and diastrophism, of stratigraphic interpretation, and of the paleontologic record run back to the question of the origin of the earth. The latter cannot be considered solved until these are worked out. But I prefer to postpone cosmic geology a moment for two other considerations.

9. In the field of Physiography or Physiographic Geology, as it is known by some investigators, the detailed mapping cannot well precede the topographic mapping discussed near the beginning of this paper. It was shown there that several generations will yet find employment before the topographic map of the world is done, unless our pace be greatly accelerated. Hence physiographic mapping will be equally delayed. But more can be said. Physiographic mapping not only cannot precede topographic work; it does not to date nearly keep up with the latter. Really but very limited and disconnected areas have been mapped and interpreted from the physiographic viewpoint. True, these are usually at more or less critical or typical places as New York City and Watkins Glen quadrangles, Tacoma quadrangle, Mooers, N. Y., Columbus, Ohio, Chicago, and Niagara, in America, and similarly restricted areas in Europe. Much excellent topical work has been done, as the Lake surveys of Scotland, Glacial features of the lobes of the Great Lakes and Prairie region of the United States, the studies of the Lake Plains in Northern Ohio, and others. But here again the problems that may be studied as topics are so numerous that one hardly knows which way to turn or where to begin. These studies already undertaken have led to many generalizations, but imperfections in some of these will undoubtedly stand out boldly as other similar or related areas are studied. Very little is known yet of the physiography, even descriptively, to say nothing of interpretation, in the portions of the earth in arid climates; and yet arid climates prevail over some 10,000,000 square miles, or one-fifth of the land area of the world. Nor do we know much as yet of the topography of the ocean floor.

Some years ago I chanced to be in a geologic conference, dealing with this phase of geology, in two sessions of which rathering striking statements were made, each by a man whose name and works are well known by scientists now before me. One man was tremendously impressed with the great size of the earth and the multiplicity of forms upon it. He said, "The earth is too big, I can't comprehend it all. I'm staggered by its display of variety; its maze of form and tangle of process." The other, approaching his problem more from the philosophic side and carrying fewer years, said, "Why, the present world is too small. I can't find nearly all the forms I can think of. I can imagine a plenty of forms I've never seen in any part of the world." Each lament points a finger in a direction which our physiographic research must take. The one must see all the world and find, record, and describe all the physiographic forms which occur, and even must uncover the past physiographies (for each geologic horizon has had its physiography as truly as it has had its distribution of sea and land), and from these ancient surfaces describe the features. The other must systematize the work of the first, classify the forms, put them into categories, resolve them into systems related to processes and stages in the process, devise formulae for describing great groups of them at once and thus make the comprehension of the whole world possible. Then must follow chapters of explanation for the types and groups.

10. In the field of Geography, whither some of our geologists have now gone to work, and whence came many of the pure geologists in days gone by, there is something yet to do. Geography is defined as that phase of science which deals with the relations existing between the physical and the cultural, between soil, topography, resource and climate on the one hand, and man and his activities on the other. The field has been cultivated, but poorly, by the historian and economist. It has been cultivated also a little by the geologist. I believe the latter has really the best equipment, but for the most effective work in this field the worker must have a good working knowledge, both of Physical Geology and Geography, and of History, Economics, Sociology, and Industries. But little work has been done in this whole field. A few score of workers are pursuing problems and the good things are beginning to come to light. While Geography has its roots in both the earth

sciences and the social sciences, it calls for some knowledge of Anthropology, Ethnology, Archeology, and even Modern Psychology. With all these contacts what then is the geographer to do? In brief, he is to work out the actual relations existing between man, and his environment, whether profitable or adverse; find geographic reasons, so far as they exist, for man's distribution, occupations, migrations, diseases, beliefs, and culture, not only in the present, but in the past. And, as his work progresses, he should be able to forecast for man, and advise; to show how man can succeed better or fail less by more careful adjustments to the environment; to show what we are doing here that we should not do here, but should do elsewhere; to show the possibilities of new lands and even of old ones, and a multitude of other things, for the good of his race. Geography holds many attractive openings for the geologist of the future and hence deserves probably the mention accorded it here, although it is not itself a branch of Geology.

11. It remains now to look into the field of cosmic geology. We are in a transition stage from rather secure trust in the Laplacian Hypothesis for the origin of the Earth and its associates, to a rather wholesome distrust of this theory and a chary approach to the Planetesimal Hypothesis. The old is decidedly unsatisfactory. The new is not wholly acceptable, but is a very suggestive working scheme. It is necessary for Geologists everywhere to adjust their *thinking* and *interpretations* to the *new theory* and to test them out together. Some weak places are found in the theory, but I am not here to discuss them. Let me mention, however, that it does not seem to account for the free oxygen in the air, and it leaves us to suppose that the chlorine in the salt of the sea came from the igneous rocks. I have made a little calculation on the latter point, a summary of which may prove interesting. Analyses show that chlorine occurs in igneous rocks to the value of about .06%. In the sea common salt constitutes about 77% of the salts and chlorine at least half of all dissolved mineral matter. The calculation shows that if a layer of igneous rocks twenty miles thick all over the earth, or seventy-five miles thick over the continents should be disintegrated, the process would liberate about as much chlorine as is now in the sea. But if this amount of igneous rock had disintegrated, where is the waste other than the chlorine? Sedimentary rocks, as formerly stated, would

not make a layer more than about a half mile thick. Thus some other source of chlorine than wasting igneous rocks must be found.

Whatever fundamental theory ultimately is established for the genesis of the earth, it will be reached by a long series of approximations. A body of facts must be built up, and over against it, a body of hypotheses. The research student must work between the two bodies. A new fact or group of facts may show the theory faulty in some particular, and make necessary its revision. The revision of the theory will point to a possible new field for investigation and the geologist will go in the quest of new truth. This truth, when found, may go beyond the theory again and thus require another revision. And so the growth of the theoretic side will proceed parallel with the growth of disclosed truth. A hypothesis for the origin of the earth must be in harmony with all known and discoverable facts of petrogenesis, paleontology, stratigraphy, and paleogeography; must be supported by all facts known of seismology, diastrophism, vulcanism, and ore deposition; and must take into account all truth discovered by astronomer, physicist, chemist and biologist. The geologist cannot complete his theoretic work until the field work is done in his own and the several related sciences.

This emphasizes the need of earnest co-operation between all scientists. "No man liveth unto himself." Men of all the enumerated branches of science are asking for the geologist's results. They, like geologists, cannot complete their tasks until facts are drawn from many related fields.

In conclusion, then, the geologist has in his own field many times more to do than he has yet accomplished along almost all lines; and he is not able to finish until other scientists have finished, because his truth is so interwoven with theirs. Science is one with many closely related ramifications. But back of all these items marshalled in previous paragraphs, items which probably amply answer the question of my subject, are the two incontrovertible facts that man is finite, while truth is infinite, and hence the whole truth will never be known. Men are at present making approximations toward it. We shall continue so to do. Our children and children's children, for many generations may also continue to do so, and with no fear of exhausting their task.

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